2025
NHT

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Write your **student number** in the boxes above. **Letter**

Chemistry

Question and Answer Book

VCE (NHT) Examination – Wednesday 21 May 2025

- Reading time is **15 minutes**: 2.00 pm to 2.15 pm
- Writing time is **2 hours 30 minutes:** 2.15 pm to 4.45 pm

Approved materials

- One scientific calculator

Materials supplied

- Question and Answer Book of 36 pages
- Data Book
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Contents

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY
VICTORIA State Government

Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on your Multiple-Choice Answer Sheet.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Below is the nutritional information from a box of biscuits.

Nutritional information	
	g per 100 g
Protein	8.90
Fat	5.20
Carbohydrates	78.5

Which one of the following is closest to the energy available for the body to use in 100.0 g of biscuits? Refer to item 12 of the Data Book.

A. 1.40×10^1 kJ

B. 7.00×10^1 kJ

C. 9.30×10^1 kJ

D. 1.60×10^3 kJ

Question 2

During cellular respiration, the oxidation of 1 mol of $C_6H_{12}O_6$ produces

A. 6 mol of electrons.

B. 12 mol of electrons.

C. 18 mol of electrons.

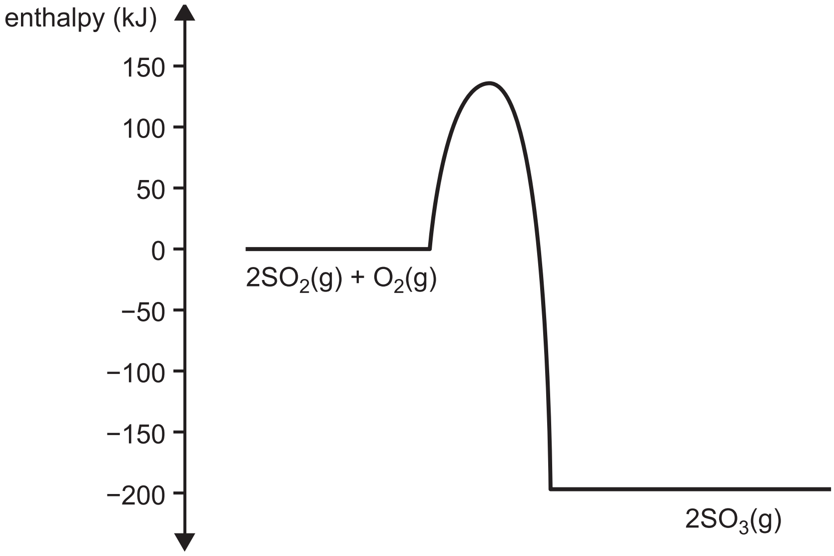
D. 24 mol of electrons.

Question 3

The reaction between sulfur dioxide gas, SO_2, and oxygen gas, O_2, to form sulfur trioxide gas, SO_3, is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The energy profile diagram for the reaction to form 2.00 mol of $SO_3(g)$ is given below.



Which is closest to the activation energy required to produce 7.00 mol of $SO_3(g)$?

A. 140 kJ

B. 330 kJ

C. 480 kJ

D. 940 kJ

Question 4

The energy content of bioethanol is 30 MJ kg^{-1}.

Which is closest to the amount of bioethanol required to produce 250 MJ of useful energy when it is used in an engine with an efficiency of 25%?

A. 2.1×10^0 kg

B. 3.3×10^1 kg

C. 2.1×10^3 kg

D. 3.3×10^4 kg

Question 5

Consider the following statements regarding a reversible reaction.

I At equilibrium, the rate of the forward reaction is zero.
II The extent of the reaction is a measure of how quickly the reactants are consumed.

Which of the statements is/are correct?

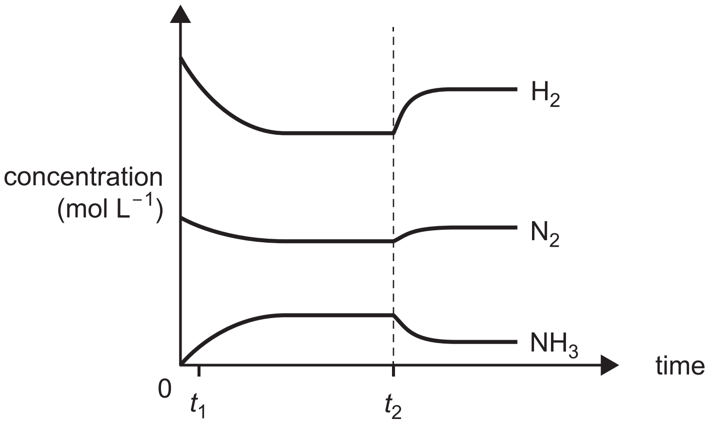
A. I only
B. II only
C. both I and II
D. neither I nor II

Use the following information to answer Questions 6 and 7.

Nitrogen gas, N_2, and hydrogen gas, H_2, react to produce ammonia gas, NH_3, according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

The concentration–time graph for the reaction is shown below.



Data: chemistryguru.com.sg

Question 6

What change to the system occurred at time t_2?

A. increase in the volume of the reaction vessel
B. increase in temperature
C. removal of NH_3 gas
D. addition of N_2 gas

Question 7

The reaction quotient, Q, at t_1 is a quantitative measure of the

A. extent of the reaction.
B. equilibrium constant.
C. activation energy.
D. reaction rate.

Question 8

An equilibrium mixture of NO_2 and N_2O_4 is contained in a reaction vessel.

The reaction is $2NO_2(g) \rightleftharpoons N_2O_4(g)$.

At a constant temperature, an increase in the rate of the forward reaction **at equilibrium** can be achieved by increasing the

A. pressure in the reaction vessel by adding an inert gas.

B. concentration of the product in the reaction vessel.

C. volume of the reaction vessel.

D. equilibrium constant.

Question 9

Consider the following statements regarding secondary cells.

I All secondary cells are rechargeable.

II All secondary cells can act as either a galvanic or an electrolytic cell.

III The polarity of the cathode during discharging is different to the polarity of the cathode during recharging.

Which of the statements are correct?

A. I and II only

B. II and III only

C. I, II and III

D. none of I, II or III

Question 10

Aluminium, Al, can be extracted from molten aluminium oxide, $Al_2O_3(l)$, by electrolysis.

Which expression represents the time needed to produce 2 mol of Al using a current of 7 A?

A. $\frac{2 \times 3 \times 96\,500}{7}$ s

B. $\frac{2 \times 96\,500}{7 \times 3}$ s

C. $\frac{7 \times 3}{2 \times 96\,500}$ s

D. $\frac{7}{2 \times 3 \times 96\,500}$ s

Question 11

Which one of the following statements is correct?

A. The carbon–carbon triple bond is the strongest type of triple bond.

B. Bonds using carbon valence electrons have the same bond energy for all bonds.

C. Carbon is the only element in the periodic table with a valence electron number of four.

D. Tetrafluoromethane, CF_4, has stronger covalent bonds than tetrachloromethane, CCl_4.

Question 12

Octane and 2-methylheptane are isomers.

Compared with octane, 2-methylheptane has a

A. lower melting point and a lower boiling point.

B. lower melting point and a higher boiling point.

C. higher melting point and a lower boiling point.

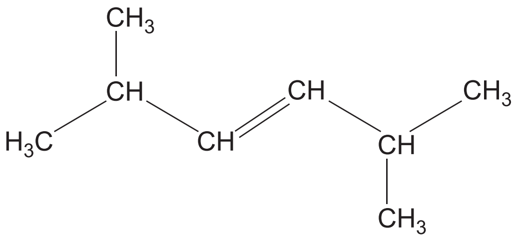
D. higher melting point and a higher boiling point.

Question 13

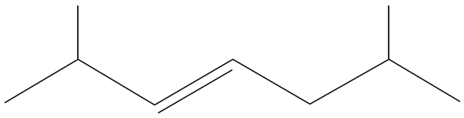
Which one of the following represents 2,5-dimethylhept-3-ene?

A. $CH_3CH_2CH(CH_3)CHCHCH(CH_3)CH_3$

B.

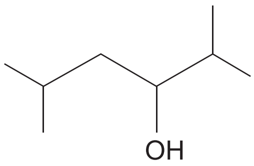


C.



D. C_8H_{16}

Question 14



What is the IUPAC name of the molecule shown above?

A. 1,4-dimethylhexan-4-ol

B. 2,5-dimethylhexan-3-ol

C. 1,1,4-trimethylpentan-2-ol

D. 1,1,4-trimethylpentan-3-ol

Question 15

Which one of the following alcohols is a secondary alcohol?

A. pentan-1-ol

B. pentan-5-ol

C. 3-methylbutan-2-ol

D. 2-methylbutan-2-ol

Question 16

One molecule of Chemical J and one molecule of ethene can undergo an addition reaction to form a new molecule.

Which one of the following could be Chemical J?

A. ethane

B. oxygen

C. iodine

D. glycerol

Question 17

Which one of the following is a possible product when a primary haloalkane reacts to produce a primary alcohol in a one-step reaction pathway?

A. Cl_2

B. HCl

C. H_2O

D. KOH

Question 18

When an excess of Molecule G was mixed with acidified potassium dichromate solution, $K_2Cr_2O_7(aq)$, the colour of the solution remained orange.

The molecular formula of Molecule G is $C_4H_{10}O$.

Which one of the following could be Molecule G?

A. 2-methylbutan-2-ol

B. 3-methylbutan-2-ol

C. 2-methylpropan-2-ol

D. butan-2-ol

Question 19

Which green chemistry principle is most consistent with designing a reaction pathway with a high atom economy?

A. catalysis

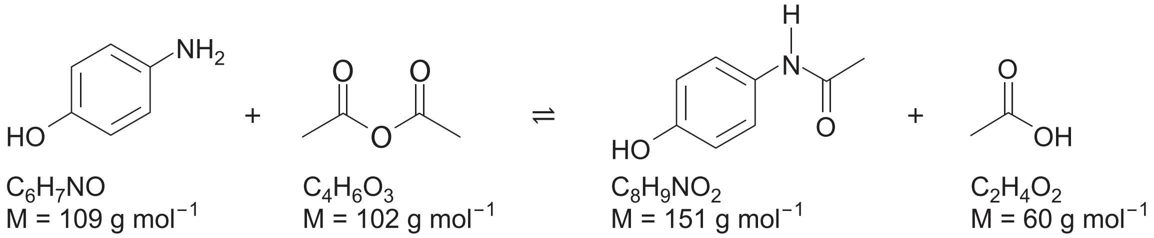
B. prevention of wastes

C. design for degradation

D. use of renewable feedstocks

Question 20

A chemist reacts 0.0730 mol of 4-aminophenol, C_6H_7NO, with 0.0750 mol of acetic anhydride, $C_4H_6O_3$, to produce paracetamol, $C_8H_9NO_2$, and ethanoic acid, $C_2H_4O_2$.



The percentage yield of $C_8H_9NO_2$ is 60.7%.

What is the mass of $C_8H_9NO_2$ collected?

A. 6.69 g

B. 6.87 g

C. 18.2 g

D. 18.7 g

Do not write in this area.

Question 21

Which one of the following statements is most correct?

A. The production of chemicals from industrial waste is sustainable.

B. Enzymes are the only catalysts consistent with green chemistry principles.

C. The aim of designing safer chemicals is to ensure that the chemicals do not readily break down.

D. Solvents made from fossil fuels are better for the environment than solvents made from plant material.

Question 22

Which one of the following correctly identifies solutions that would react **directly** with a compound to test for the presence of carbon–carbon double bonds and carboxyl functional groups respectively in the compound?

	Carbon–carbon double bond	**Carboxyl functional group**
A.	acidified potassium dichromate	limewater
B.	acidified potassium dichromate	sodium hydrogen carbonate
C.	bromine water	limewater
D.	bromine water	sodium hydrogen carbonate

Question 23

Consider the following statements regarding melting point determination of a sample.

I If a sample starts melting at 49 °C and is not fully melted at 53 °C, then the sample is a mixture.

II If the melting point of a sample is lower than expected, then the sample is a mixture.

Which of the statements is/are correct?

A. I only

B. II only

C. both I and II

D. neither I nor II

Question 24

10.0 mL of 0.882 M hydrogen peroxide, H_2O_2, solution is titrated with a 0.100 M solution of acidified potassium permanganate, $KMnO_4$. The equation for the reaction is shown below.

$$2MnO_4^-(aq) + 6H^+(aq) + 5H_2O_2(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

What volume of $KMnO_4(aq)$ is expected to react completely with the 10.0 mL of $H_2O_2(aq)$?

A. 17.7 mL

B. 22.1 mL

C. 35.3 mL

D. 88.2 mL

Question 25

Which one of the following sets of wave numbers for the infrared spectrum is consistent with $CH_3COCH_2CONH_2$? Refer to item 22 of the Data Book.

A. 1720–1840 cm^{-1} and 1660–1745 cm^{-1}

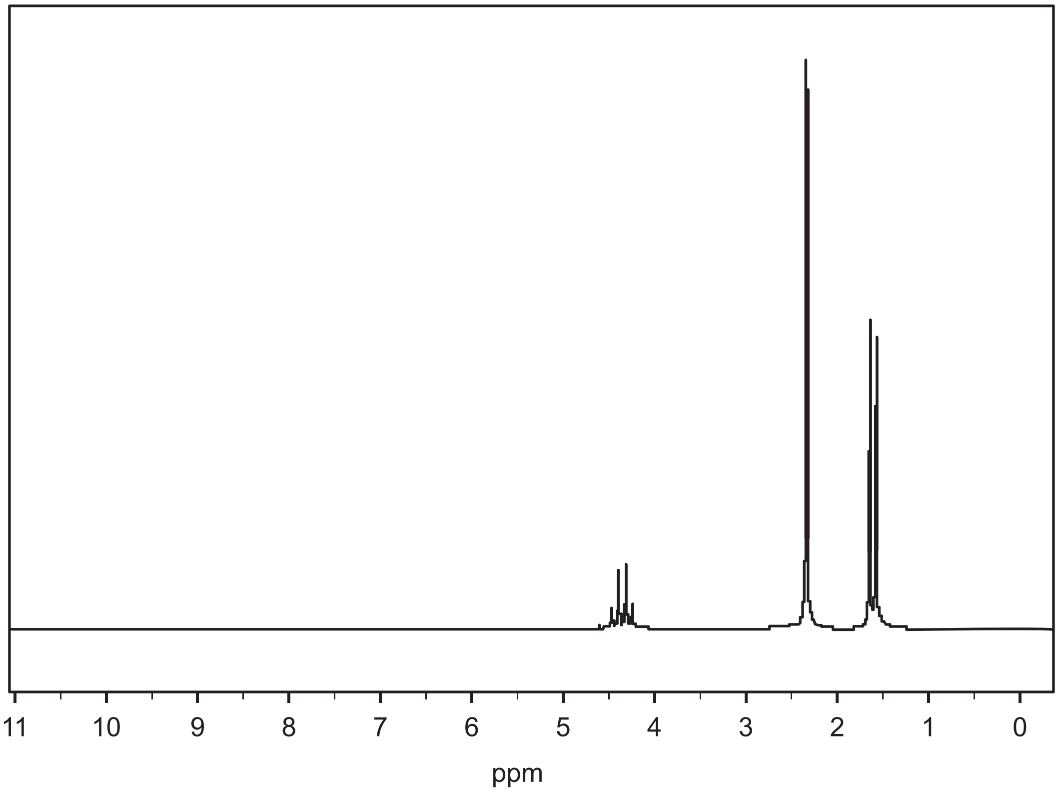
B. 1720–1840 cm^{-1} and 1680–1850 cm^{-1}

C. 1630–1680 cm^{-1} and 1660–1745 cm^{-1}

D. 1630–1680 cm^{-1} and 1680–1850 cm^{-1}

Question 26

The ^1H NMR spectrum of an organic compound is shown below. There are three peaks: a quartet, a singlet and a doublet.



Data: National Institute of Advanced Industrial Science and Technology, Japan, 2024

What is the organic compound?

A. $(CH_3)_2CHOH$

B. CH_3CH_2COOH

C. $CH_3COOCH_2CH_3$

D. $CH_3COCHClCH_3$

Question 27

The concentration of an active ingredient in a solution is determined using high performance liquid chromatography (HPLC).

The calibration curve would be constructed by running solutions of the active ingredient with

A. a range of different known concentrations at different pressures through the HPLC column.

B. a range of different known concentrations at the same pressure through the HPLC column.

C. the same known concentration at the same pressure through the HPLC column.

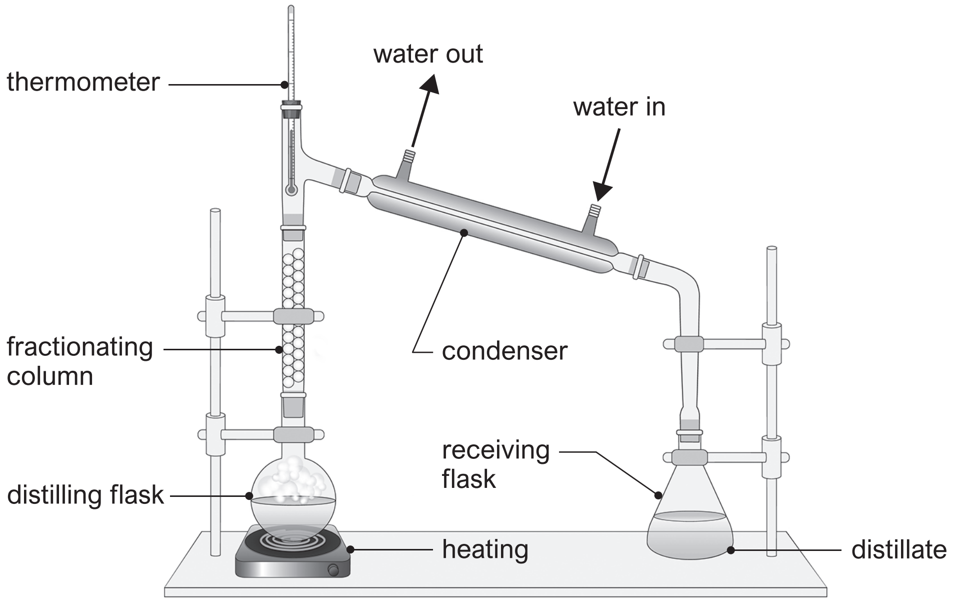
D. the same known concentration at different pressures through the HPLC column.

Question 28

The following table shows the composition of an oil.

Component	Boiling point (°C)	Percentage composition (%)
α-pinene	156	15
1,8-cineole	176	85

Victoria distilled this oil in the fractional distillation apparatus shown in the diagram below.



Source: rktz/Shutterstock.com

Victoria monitored the temperature at the top of the fractionating column during the distillation process. At the end of the distillation, some liquid remained in the distilling flask.

Which one of the following statements is true if the distillation produced a distillate of 80% pure *α*-pinene?

A. The melting point of the distillate was greater than 156 °C.

B. The temperature of the distillate collected in the receiving flask was 156 °C.

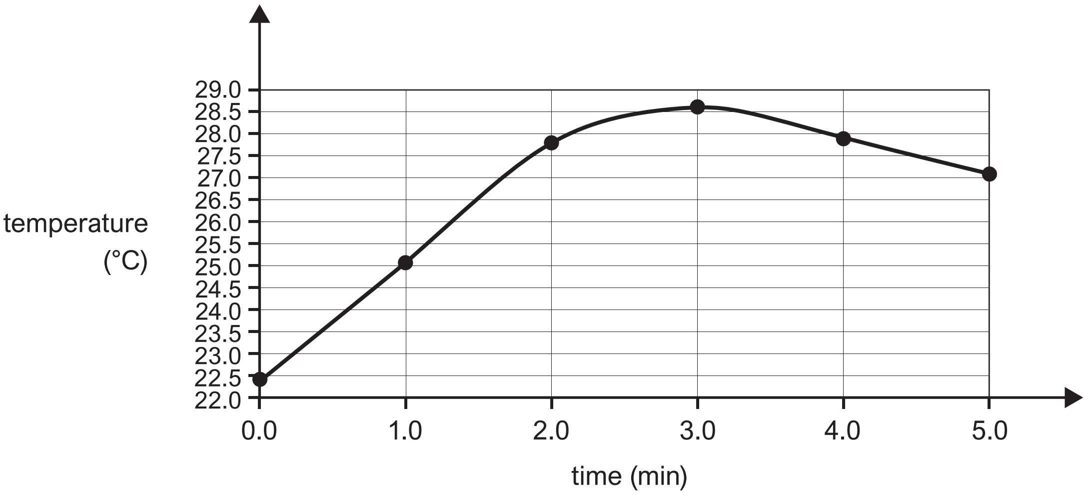
C. The temperature of the liquid in the distilling flask was greater than 156 °C during the distillation.

D. The distillation was stopped as soon as the temperature at the top of the fractionating column reached 156 °C.

Question 29

A calorimeter with a digital temperature probe was calibrated. The calorimeter was then used to measure the enthalpy of a chemical reaction.

The graph below shows the six temperatures recorded in the first five minutes from when the reactants were mixed.



The graph was used to calculate the enthalpy for the reaction.

Which one of the following would best improve the determination of the maximum temperature reached by the calorimeter?

A. performing the experiment at SLC

B. using a different chemical reaction

C. recording temperatures every 20 seconds

D. recording the temperature for 10 minutes

Question 30

Consider the following statements.

I Identified mistakes should not be included in subsequent data analysis and reporting.

II An outlier in an otherwise highly precise set of 50 measurements indicates a systematic error.

Which of the statements is/are correct?

A. I only

B. II only

C. both I and II

D. neither I nor II

End of Section A

Section B

Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.
- Ensure that chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (10 marks)

a. Amylose (starch) can be broken down into its monomers in the digestive system. Refer to item 25 of the Data Book.

i. State the monomer of amylose. 1 mark

ii. What is the degree of unsaturation of the monomer of amylose? 1 mark

iii. Name the **type** of reaction that breaks amylose down into its monomers. 1 mark

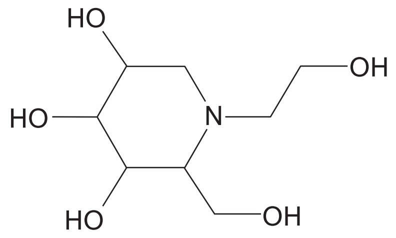
b. A reaction involved in the breakdown of amylose is catalysed by the enzyme *α*-glucosidase.

The function of *α*-glucosidase can be affected by the pH of the digestive system.

Explain, in terms of structure, why enzyme function can be affected by changes in pH. 3 marks

Question 1 continues on the next page.

c. Miglitol, $C_8H_{17}NO_5$, can act as a reversible, competitive enzyme inhibitor for the reaction catalysed by *α*-glucosidase. The structure of miglitol is shown below.



i. Identify a functional group in miglitol. 1 mark

ii. Describe how miglitol inhibits the breakdown of amylose. 2 marks

iii. How many chiral centres are present in one molecule of miglitol? 1 mark

Question 2 (7 marks)

The equation for the complete combustion of octane, C_8H_{18}, is

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

a. Calculate the mass of CO_2 formed when 1.50 mol of C_8H_{18} is completely combusted. 2 marks

b. Explain why the combustion of C_8H_{18} is exothermic with general reference to bond making and bond breaking. 2 marks

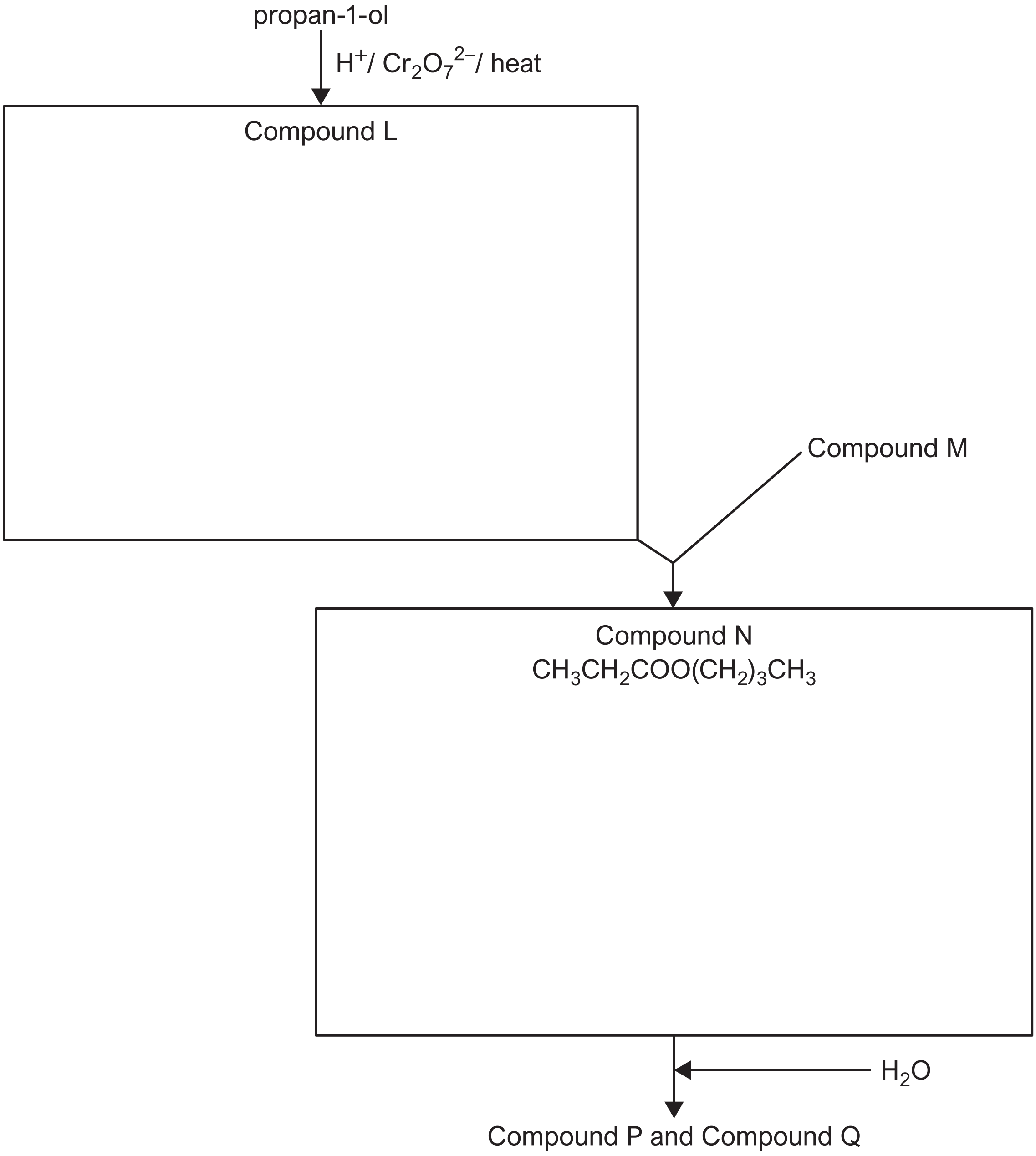
c. In a controlled combustion experiment, 2.0 mol of C_8H_{18} is combusted with 21.0 mol of O_2. No pure carbon is produced in the reaction. At the end of the experiment, no reactants remained.

i. Identify a product of the reaction that is produced in addition to the products of the complete combustion of C_8H_{18}. 1 mark

ii. Justify your answer to **part c.i**. 2 marks

Question 3 (10 marks)

Consider the following reaction pathway beginning with propan-1-ol.



a. How many structural isomers that are alcohols exist for propan-1-ol? Do not include propan-1-ol in your tally of isomers. 1 mark

b. Propan-1-ol reacts with $H^+/ Cr_2O_7^{2-}$ to produce Compound L.

Draw the structural formula of Compound L in the box provided above. 1 mark

c. Compound L and Compound M react to produce Compound N. The semi-structural formula of Compound N is shown in the reaction pathway above.

Draw the skeletal structure of Compound N in the box provided above. 1 mark

d. **i.** Identify a catalyst that will increase the rate of the reaction to produce Compound N. 1 mark

ii. Write the IUPAC name for Compound N. 1 mark

e. Compounds P and Q can be produced under certain conditions in a reaction between Compound N and H_2O.

Compound P reacts with acidified potassium permanganate, $KMnO_4$, resulting in a colourless solution.

Write the IUPAC name of Compound P. 1 mark

f. Calculate the percentage atom economy for producing Compound P from the reaction between Compound N and H_2O. The molar mass of Compound N is 130 g mol^{-1}. 2 marks

g. Compound P and Compound Q can be separated because they have different boiling points.

Which one of the two compounds will have the higher boiling point? Justify your answer by referring to the functional groups of the two molecules. 2 marks

Question 4 (7 marks)

Consider the following equilibrium reaction.

$$CO_2(g) + CF_4(g) \rightleftharpoons 2COF_2(g)$$

2.00 mol of $CO_2(g)$ and 2.00 mol of $CF_4(g)$ are injected into an empty, sealed 2.00 L container at 1000 °C and allowed to reach equilibrium.

a. **i.** When the system reaches equilibrium at 1000 °C, the concentration of $CF_4(g)$ is 0.74 M.

What is the equilibrium concentration of $COF_2(g)$? 2 marks

ii. What is the value of the equilibrium constant at 1000 °C? 2 marks

b. An additional 1.00 mol of CO_2 at 1000 °C is injected into the 2.00 L sealed container.

i. State what happens to the reaction quotient, *Q*, immediately after the CO_2 is injected. 1 mark

ii. Explain how the addition of the CO_2 affects the yield of the reaction. 2 marks

Question 5 (8 marks)

A constant current of 1.80 A at a potential difference of 4.85 V was passed through a heating coil to calibrate a calorimeter. The temperature of the water increased by 2.1 °C. The calibration factor was calculated as 374 J $°C^{-1}$.

a. **i.** Calculate the time that the current was passed through the heating coil during the calibration of the calorimeter. 2 marks

ii. A student correctly states, ‘the calorimeter contained less than 100 g of water’. Justify this statement with reference to the results of the experiment. 3 marks

b. The reaction below is performed in the calibrated calorimeter.

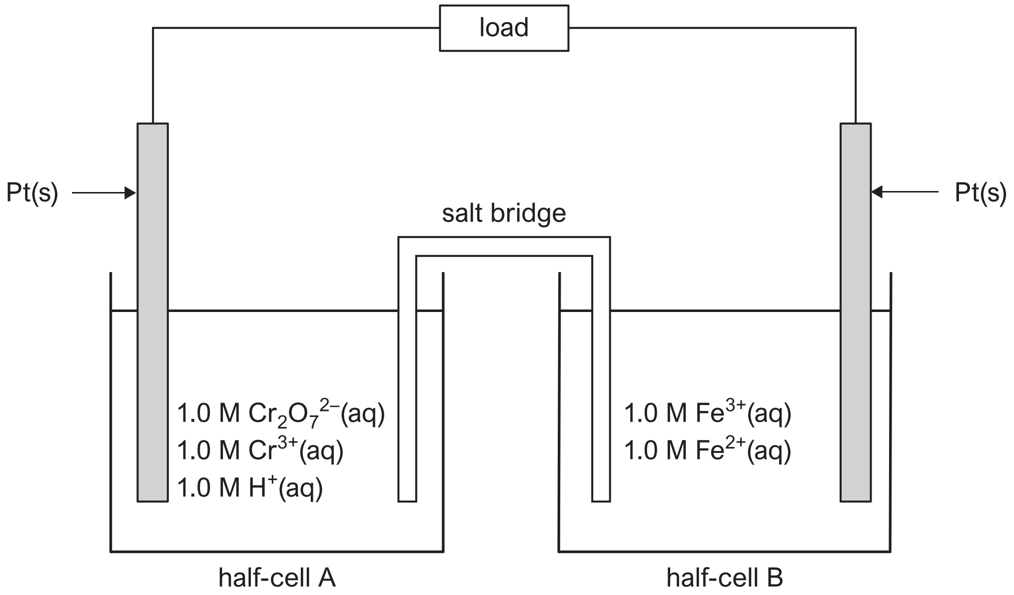
$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

80.0 mL of 0.40 M H_2SO_4(aq) and 0.060 mol of NaOH(aq) were reacted in the calorimeter.

Calculate the amount, in mol, of H_2SO_4(aq) in excess. 3 marks

Question 6 (8 marks)

Consider the following galvanic cell and refer to item 1 of the Data Book.



a. Write the equation for the overall reaction that occurs in the galvanic cell. 2 marks

b. **i.** Identify the oxidising agent for the galvanic cell reaction. 1 mark

ii. Justify your answer to **part b.i** by using oxidation numbers. 1 mark

c. **i.** Calculate the change in mass of Cr^{3+}(aq) in half-cell A for every 1.0 mol of electrons that passes through the load. 2 marks

ii. Explain a change to the electrode of half-cell B that would increase the voltage produced by the galvanic cell. 2 marks

Question 7 (9 marks)

a. Rechargeable silver–zinc cells are used in the space industry. When the cell is recharging, the following reactions occur at the electrodes.

Electrode X: silver, Ag, reacts to form silver(I) oxide, Ag_2O

$$2Ag + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$$

Ag_2O then reacts to form silver(II) oxide, AgO

$$Ag_2O + 2OH^- \rightarrow 2AgO + H_2O + 2e^-$$

Electrode Y: $Zn(OH)_2 + 2e^- \rightarrow Zn + 2OH^-$ $E^0 = -1.22$ V

i. State the polarity of electrode Y during recharging. 1 mark

ii. Write the overall recharging reaction that occurs at electrode X. 1 mark

iii. Write the overall recharging reaction for the silver–zinc cell. 1 mark

iv. The half equation to form silver ions is

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

The standard electrode potential for this reaction can be determined using item 1 of the Data Book.

Silver(I) ions, Ag^+, are not formed during the recharge reaction.

Explain why it is possible to form Ag_2O and AgO, but not Ag^+ during the recharge reaction of the silver–zinc cell. Use the standard half-cell potential of the recharging reaction that occurs at electrode Y in your answer. 3 marks

b. Artificial photosynthesis can be used to produce hydrogen from water in acidic conditions.

i. What activates the flow of electrons in an artificial photosynthesis system? 1 mark

ii. Write the reduction half equation that occurs during artificial photosynthesis. 1 mark

iii. Water acts in the same role in both the natural and artificial photosynthesis reactions.

What is this role? 1 mark

Question 8 (13 marks)

Compound Z is an organic compound. It does not contain any oxygen or nitrogen atoms.

The structure of Compound Z is identified using a combination of laboratory and spectroscopic tests.

Excess Compound Z is mixed with bromine solution, $Br_2(aq)$. The colour of the mixture rapidly changes from brown to colourless.

a. **i.** What does the result of the test reveal about the structure of Compound Z? 1 mark

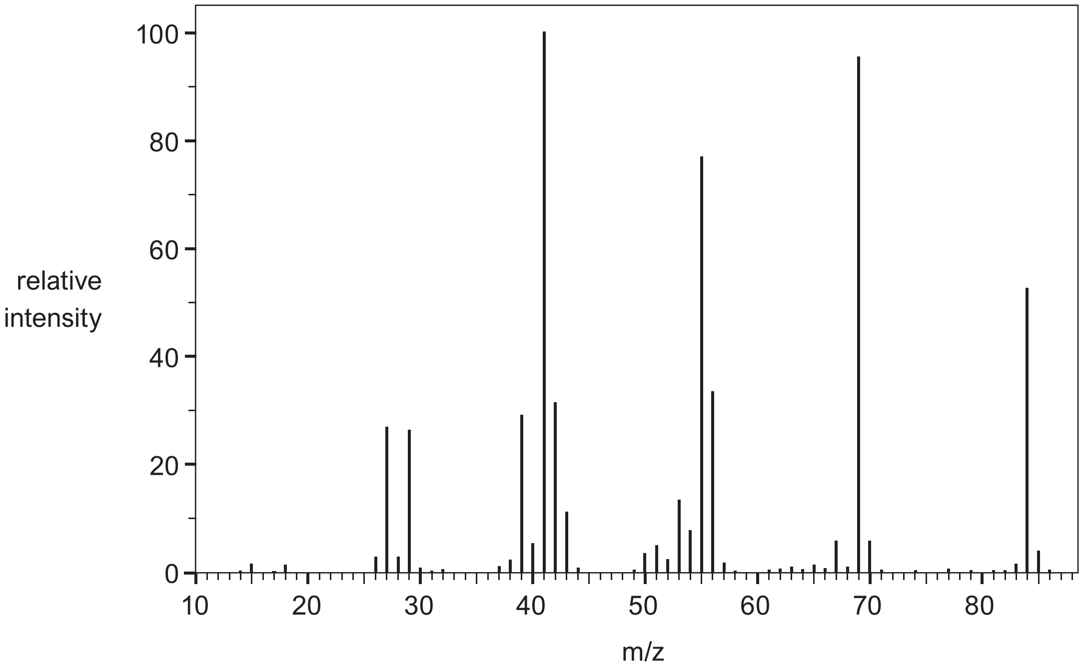
____

____

ii. Identify the type of chemical reaction that results in the colour change. 1 mark

____

b. The mass spectrum of Compound Z is shown below.



Data: National Institute of Advanced Industrial Science and Technology, Japan, 2024

i. State the molecular formula of Compound Z. 1 mark

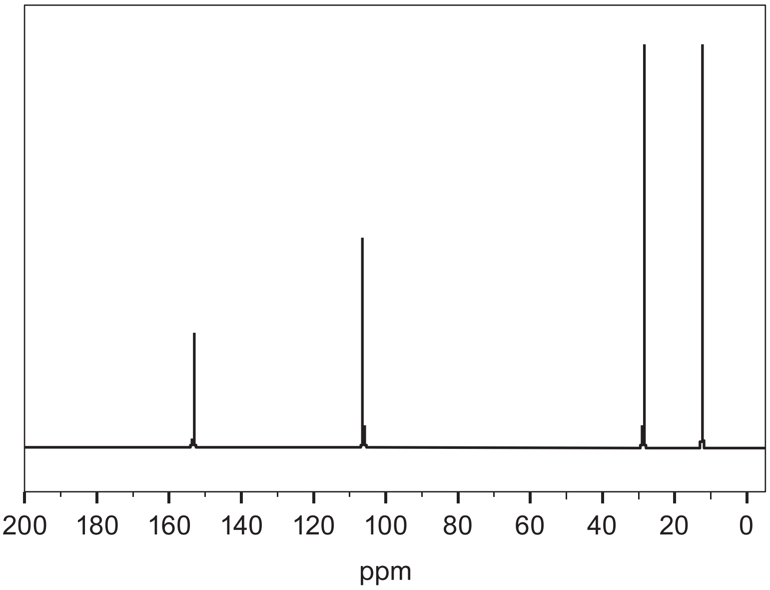
____

ii. State the formula of the species that is responsible for the peak at 55 m/z. 1 mark

____

c. Calculate the mass of iodine that reacts with 100 g of Compound Z. 3 marks

d. The ^{13}C NMR spectrum of Compound Z is shown below.



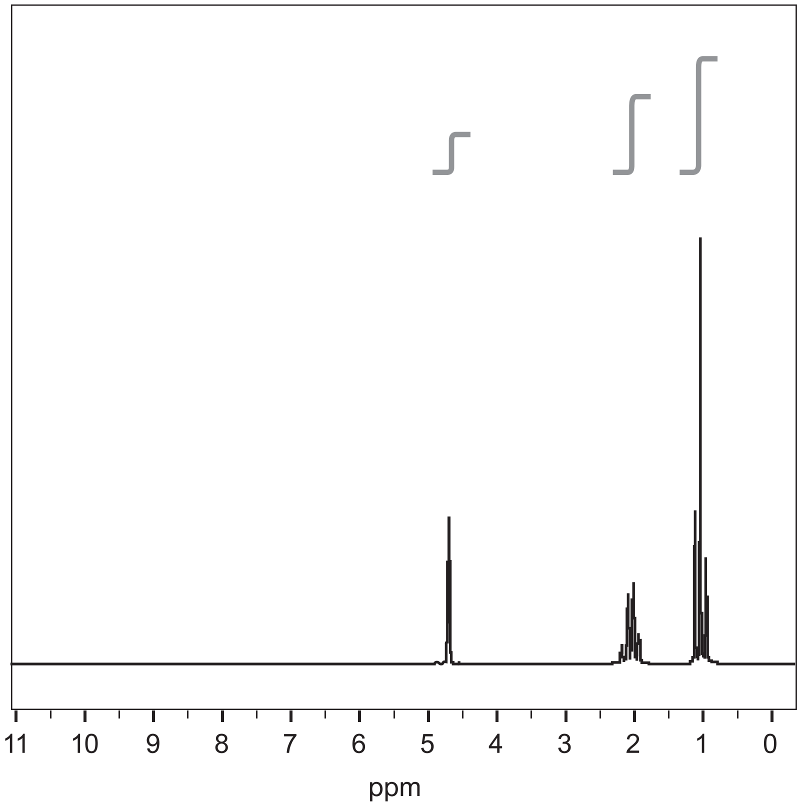
Data: National Institute of Advanced Industrial Science and Technology, Japan, 2024

Compare the four peaks in the ^{13}C NMR spectrum for Compound Z with the molecular formula of Compound Z in **part b.i.**

What information do the four peaks in the ^{13}C NMR spectrum together with the molecular formula provide about the arrangement of the carbon atoms in Compound Z? 2 marks

Question 8 continues on the next page.

e. The high-resolution ^1H NMR spectrum, indicative integration curves and a chemical shift table for Compound Z are shown below. Refer to item 24 of the Data Book.



Chemical shift (ppm)	Splitting pattern
4.7	singlet
2.0	quartet
1.0	triplet

Data: adapted from National Institute of Advanced Industrial Science and Technology, Japan, 2024

Consider the chemical shift and the size of the integration curve for the peak at 1.0 ppm.

What does this information indicate about the structure of Compound Z? 2 marks

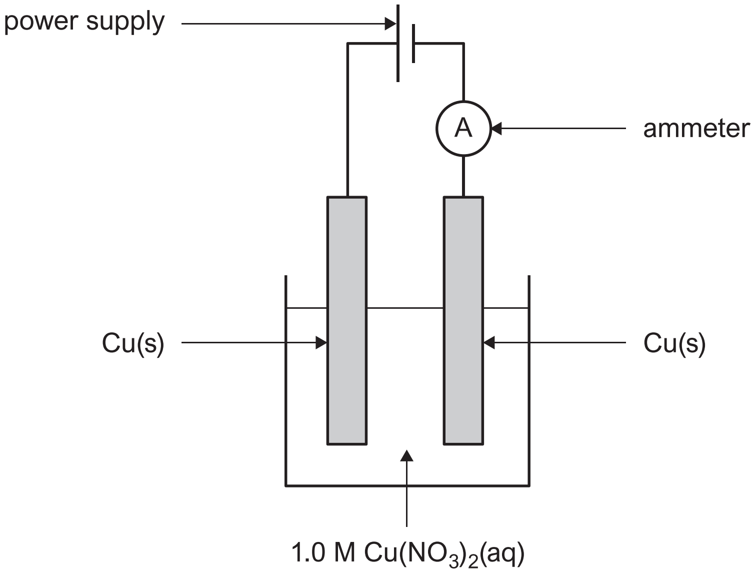
f. Draw the structural formula of Compound Z, considering all the information provided in this question. Use the space below. 2 marks

Question 9 (10 marks)

Kim investigated the application of Faraday's Laws using an electrolytic cell.

Kim designed and performed the following method.

1. Clean two 1 cm × 6 cm copper strips with steel wool.
2. Label one strip positive and the other negative.
3. Record the initial mass of each strip.
4. Add 200 mL of 1.0 M copper(II) nitrate, $Cu(NO_3)_2$, solution to a 250 mL beaker.
5. Place the copper strips on opposite sides of the 250 mL beaker so that the copper strips do not touch.
6. Connect the positive terminal of a 6.0 V direct current power supply to the copper strip labelled positive and the negative terminal of the power supply to the copper strip labelled negative.
7. Turn on the power supply.
8. Record the current in the circuit using an ammeter connected as shown in the diagram.
9. Record observations about any changes occurring in the beaker.
10. Turn off the power supply after 20.0 minutes.
11. Detach the copper strips from the power supply, rinse with distilled water and allow to dry.
12. Record the final mass of each copper strip.
13. Repeat steps 1–12 twice.
14. Calculate the average change in mass for each electrode.



a. **i.** What is the purpose of determining the average in Step 14? 1 mark

ii. Explain why 1.0 M $Cu(NO_3)_2$ solution is a safer choice of electrolyte than 1.0 M copper(II) chloride, $CuCl_2$, solution if the method on page 28 is followed. 2 marks

iii. What variable is Kim trying to control by using copper for both electrodes? 1 mark

Question 9 continues on the next page.

b. Kim calculated the expected change in mass of both the electrodes to be 0.185 g.

Table 1 shows the data Kim collected.

Electrode polarity	Average change in mass (g)	Observations
Positive	0.179 g decrease	Small bubbles at the surface of the electrode.
Negative	0.168 g increase	Dark-coloured substance collecting on the surface of electrode. Some particles observed below the electrode.

Table 1: Data

i. Identify **one** assumption that Kim made about the current to calculate the expected change in mass of the electrodes. 1 mark

ii. Use the data in Table 1 to explain why the measurements from the negative electrode would provide less accurate results for testing the application of Faraday's Laws than the measurements from the positive electrode. 2 marks

c. To investigate Faraday's Laws, Kim repeated the procedure, under the same conditions, using silver, Ag, electrodes with a solution of 200 mL of 1.00 M silver nitrate, $AgNO_3$.

Kim's hypothesis is that the amount of substance (mol) reacted at the positive electrode is directly proportional to the charge of the metal cation in the electrolyte.

Kim's summary of results is presented in Table 2 below.

Electrode material	Electrolyte	Average mass of metal loss at positive electrode (g)	Average amount of metal loss at positive electrode (mol)
Copper, Cu(s)	$Cu(NO_3)_2(aq)$	0.179	2.82×10^{-3}
Silver, Ag(s)	$AgNO_3(aq)$	0.603	5.59×10^{-3}

Table 2: Results

i. Explain whether the results in Table 2 support Kim's hypothesis. 2 marks

ii. Use the information in Table 2 to write a valid conclusion for the experiment. 1 mark

Question 10 (8 marks)

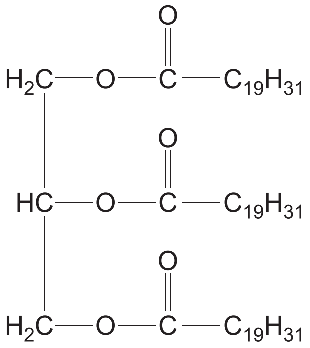
> Development of low-cost, sustainable, and environmentally friendly biodiesel is a key focus in the energy industry worldwide. It is known that selecting suitable materials and optimising [the] transesterification process are crucial in biodiesel production.[1]
>
> [A] transesterification reaction is a reversible reaction, so if the reaction has reached equilibrium, the reaction can shift back toward the reactants. The forward reaction is exothermic.[2]

Source 1: Ishak, S, Kamari, A. 'A review of optimum conditions of transesterification process for biodiesel production from various feedstocks, *Int. J. Environ. Sci. Technol.,* vol. 16, 2019, pp. 2481–2502

Source 2: Adapted from Rosyadi, I, et al. 'Biodiesel Characteristics of Tuna Fish Bio-Oil Waste in the Transesterification Process with Variation of Reaction Time and Stirring Speed.' *IOP Conference Series: Materials Science and Engineering*, vol. 909, no. 1, 1 December 2020, p. 012029

Biodiesel can be produced using triarachidonin, $C_{63}H_{98}O_6$, and ethanol, C_2H_6O.

The structure of $C_{63}H_{98}O_6$ is shown below.



a. **i.** Write the chemical equation for the production of biodiesel. 1 mark

ii. Discuss the reaction conditions that increase the rate and optimise the yield of biodiesel produced from the reaction between $C_{63}H_{98}O_6$ and C_2H_6O. 4 marks

b. Biodiesel is an alternative to fossil fuels. It is commonly produced from vegetable oils and animal fats.

Discuss the sustainability of the use of biodiesel as a fuel. In your response, refer to United Nations Sustainable Development Goal 13: Climate action. 3 marks

End of examination questions

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2025

NHT

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2025 Data Book

Contents pages

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VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

VICTORIA State Government

1. Electrochemical series

Reaction	**Standard electrode potential (E^0) in volts at 25 °C**
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$PbO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Pb^{2+}(aq) + 2H_2O(l)$	+1.47
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.36
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	−0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	−1.66
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.37
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	−2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.04

2. Chemical relationships

Name	**Formula**
amount of substance (number of moles)	$n = \frac{m}{M}$; $n = cV$; $n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
chemical calibration factor (CF) for calorimetry	$\text{CF} = \frac{E}{\Delta T}$
electrical calibration factor (CF)	$\text{CF} = \frac{VIt}{\Delta T}$
thermal energy transferred	$q = mc\Delta T$
molar enthalpy change	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
amount of electrons (number of moles)	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$
equilibrium constant	$K = \frac{[C]^c \times [D]^d \times \ldots}{[A]^a \times [B]^b \times \ldots}$ for the equation $a\text{A} + b\text{B} + \ldots \rightleftharpoons c\text{C} + d\text{D} + \ldots$

3. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25 °C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25 °C	d	1.0 g mL^{-1}
molar latent heat of vaporisation of water at 25 °C	$\Delta H_{vap}(H_2O)$	+44.0 kJ mol^{-1}
molar latent heat of vaporisation of water at 100 °C	$\Delta H_{vap}(H_2O)$	+40.7 kJ mol^{-1}

4. Unit conversions

Measured value	Conversion
0 °C	273 K
100 kPa	0.987 atm
1 litre (L)	1 dm^3 or 1×10^{-3} m^3 or 1×10^3 cm^3 or 1×10^3 mL

5. Metric prefixes

The following prefixes are commonly used within the International System of Units (SI) to modify the base units and express quantities in multiples or fractions of those units.

Prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

6. Acid-base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

7. Colours of selected conjugate redox reagents

Redox reagent in oxidised state		Redox reagent in reduced state	
Name/formula	**Colour**	**Name/formula**	**Colour**
bromine, Br_2	brown	bromide ion, Br^-	colourless
chlorine, Cl_2	yellow/green	chloride ion, Cl^-	colourless
copper(II) ion, Cu^{2+}	blue	copper(I) ion, Cu^+	red
dichromate ion, $Cr_2O_7^{2-}$	orange	chromium(III) ion, Cr^{3+}	green
iodine, I_2	brown in aqueous solutions	iodide ion, I^-	colourless
iron(III) ion, Fe^{3+}	yellow/brown	iron(II) ion, Fe^{2+}	pale green
manganese(IV) dioxide, MnO_2	black/brown	manganese(II) ion, Mn^{2+}	very pale pink
permanganate ion, MnO_4^-	intense purple	manganese(II) ion, Mn^{2+}	very pale pink

8. Formulas and charges for selected ions

Cations

1+		2+		3+	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
ammonium	NH_4^+	barium	Ba^{2+}	aluminium	Al^{3+}
copper(I)	Cu^+	calcium	Ca^{2+}	chromium(III)	Cr^{3+}
hydronium	H_3O^+	copper(II)	Cu^{2+}	iron(III)	Fe^{3+}
lithium	Li^+	iron(II)	Fe^{2+}	**4+**	
potassium	K^+	lead(II)	Pb^{2+}	titanium(IV)	Ti^{4+}
silver	Ag^+	magnesium	Mg^{2+}		
sodium	Na^+	mercury(II)	Hg^{2+}		
		nickel(II)	Ni^{2+}		
		tin(II)	Sn^{2+}		
		zinc	Zn^{2+}		

Anions

1−		2−		3−	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
bromide	Br^-	carbonate	CO_3^{2-}	citrate	$C_6H_5O_7^{3-}$
chlorate	ClO_3^-	chromate	CrO_4^{2-}	nitride	N^{3-}
chloride	Cl^-	dichromate	$Cr_2O_7^{2-}$	phosphate	PO_4^{3-}
chlorite	ClO_2^-	monohydrogen phosphate	HPO_4^{2-}		
cyanide	CN^-	oxide	O^{2-}		
dihydrogen phosphate	$H_2PO_4^-$	peroxide	O_2^{2-}		
ethanoate	CH_3COO^-	sulfate	SO_4^{2-}		
fluoride	F^-	sulfide	S^{2-}		
hydrogen carbonate	HCO_3^-	sulfite	SO_3^{2-}		
hydrogen sulfate	HSO_4^-	thiosulfate	$S_2O_3^{2-}$		
hydrogen sulfide	HS^-				
hydrogen sulfite	HSO_3^-				
hydroxide	OH^-				
hypochlorite	ClO^-				
iodide	I^-				
nitrate	NO_3^-				
nitrite	NO_2^-				
perchlorate	ClO_4^-				
permanganate	MnO_4^-				

9. Solubility table

Salts	Soluble	Insoluble
sodium	All	None
potassium		
ammonium		
nitrate		
ethanoate		
bromide, chloride, iodide	Most are soluble.	lead(II), silver, $CuBr_2$, CuI_2
sulfate	Most are soluble.	barium, calcium, lead(II), silver
carbonate	Group 1 ions, ammonium	Most are insoluble.
phosphate	Group 1 ions, ammonium	Most are insoluble.
hydroxide	Group 1 ions, ammonium	Most are insoluble.

10. Average bond enthalpies at 25 °C – single bonds

ΔH (kJ mol^{-1})								
	C	H	O	N	Br	Cl	F	I
C	346	414	358	286	285	324	492	228
H	414	436	463	391	366	431	567	298
O	358	463	144	214	201	206	191	234
N	286	391	214	158		192	278	

11. Average bond enthalpies at 25 °C – multiple bonds

Bond	**ΔH (kJ mol^{-1})**
C=C	614
C≡C	839
C=N	615
C≡N	890
C=O	804
O=O	498
N=N	470
N≡N	945

12. Energy content of food groups

The energy that is typically available for the body to use as a result of the digestion and absorption of fats and oils, proteins and carbohydrates is shown in the table below. These values may vary based on the specific composition of foods and individual metabolic factors.

Food	Energy content (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

13. Molar enthalpies of combustion

The molar enthalpies of combustion in the following table are calculated at SLC (25 °C and 100 kPa) with combustion products being $CO_2(g)$ and $H_2O(l)$. Enthalpies of combustion, ΔH, for the substances in this table are reported for one mole of fuel and are shown as negative values, indicating the exothermic nature of the combustion reaction.

$$C_2H_6(g) + 3\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H = -1560 \text{ kJ mol}^{-1}$$

Fuel	Formula	Molar enthalpy of combustion (kJ mol^{-1})
hydrogen	$H_2(g)$	−286
methane	$CH_4(g)$	−890
ethane	$C_2H_6(g)$	−1560
propane	$C_3H_8(g)$	−2220
butane	$C_4H_{10}(g)$	−2880
octane	$C_8H_{18}(l)$	−5470
methanol	$CH_3OH(l)$	−726
ethanol	$C_2H_5OH(l)$	−1370
carbon (graphite)	$C(s)$	−394
glucose	$C_6H_{12}O_6(s)$	−2840

14. Heats of combustion of selected blended fuels

Blended fuels are mixtures of compounds with different mixture ratios and, hence, determination of a generic molar enthalpy of combustion is not realistic. The values provided in the following table are typical values for heats of combustion at SLC (25 °C and 100 kPa) with combustion products being $CO_2(g)$ and $H_2O(l)$. Values for heats of combustion will vary due to the composition of the different fuels. Additionally, for natural gas, the values may vary based on the source and processing.

Fuel	State	Heat of combustion ($kJ\ g^{-1}$)	Heat of combustion ($kJ\ mL^{-1}$)
diesel	liquid	45	37
kerosene	liquid	46	37
natural gas	gas	54	0.035
petrol	liquid	45	34

15. Heats of combustion of selected biofuels

The following table provides typical values for the heat of combustion of selected biofuels. The values may vary significantly, particularly for biogas, depending on the source of the biofuel and, hence, its composition. The amount of energy consumed during any purification process must also be considered when determining the net energy obtained from a biofuel.

Fuel	State	Heat of combustion ($kJ\ g^{-1}$)
biodiesel	liquid	Approx 37
bioethanol	liquid	29.7
biogas	gas	14–24 This depends on its methane content, which can vary from 45% to 75% methane by volume, depending on its source. The other main constituent is CO_2, which does not burn.

16. Periodic table of the elements

atomic number	**79**
79 2.5	electronegativity value
Au	symbol of element
197.0	relative atomic mass
gold	name of element

1 2.2 **H** 1.0 hydrogen								
3 1.0 **Li** 6.9 lithium	**4** 1.6 **Be** 9.0 beryllium							
11 0.9 **Na** 23.0 sodium	**12** 1.3 **Mg** 24.3 magnesium							
19 0.8 **K** 39.1 potassium	**20** 1.0 **Ca** 40.1 calcium	**21** 1.4 **Sc** 45.0 scandium	**22** 1.5 **Ti** 47.9 titanium	**23** 1.6 **V** 50.9 vanadium	**24** 1.7 **Cr** 52.0 chromium	**25** 1.6 **Mn** 54.9 manganese	**26** 1.8 **Fe** 55.8 iron	**27** 1.9 **Co** 58.9 cobalt
37 0.8 **Rb** 85.5 rubidium	**38** 1.0 **Sr** 87.6 strontium	**39** 1.2 **Y** 88.9 yttrium	**40** 1.3 **Zr** 91.2 zirconium	**41** 1.6 **Nb** 92.9 niobium	**42** 2.2 **Mo** 96.0 molybdenum	**43** 1.9 **Tc** (98) technetium	**44** 2.2 **Ru** 101.1 ruthenium	**45** 2.3 **Rh** 102.9 rhodium
55 0.8 **Cs** 132.9 caesium	**56** 0.9 **Ba** 137.3 barium	**57–71** lanthanoids	**72** 1.3 **Hf** 178.5 hafnium	**73** 1.5 **Ta** 180.9 tantalum	**74** 2.4 **W** 183.8 tungsten	**75** 1.9 **Re** 186.2 rhenium	**76** 2.2 **Os** 190.2 osmium	**77** 2.2 **Ir** 192.2 iridium
87 0.7 **Fr** (223) francium	**88** 0.9 **Ra** (226) radium	**89–103** actinoids	**104** **Rf** (261) rutherfordium	**105** **Db** (262) dubnium	**106** **Sg** (266) seaborgium	**107** **Bh** (264) bohrium	**108** **Hs** (267) hassium	**109** **Mt** (268) meitnerium
		57 1.1 **La** 138.9 lanthanum	**58** 1.1 **Ce** 140.1 cerium	**59** 1.1 **Pr** 140.9 praseodymium	**60** 1.1 **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** 1.2 **Sm** 150.4 samarium	**63** **Eu** 152.0 europium
		89 1.1 **Ac** (227) actinium	**90** 1.3 **Th** 232.0 thorium	**91** 1.5 **Pa** 231.0 protactinium	**92** 1.4 **U** 238.0 uranium	**93** 1.4 **Np** (237) neptunium	**94** 1.3 **Pu** (244) plutonium	**95** 1.3 **Am** (243) americium

								2 **He** 4.0 helium
			5 2.0 **B** 10.8 boron	**6** 2.6 **C** 12.0 carbon	**7** 3.0 **N** 14.0 nitrogen	**8** 3.4 **O** 16.0 oxygen	**9** 4.0 **F** 19.0 fluorine	**10** **Ne** 20.2 neon
			13 1.6 **Al** 27.0 aluminium	**14** 1.9 **Si** 28.1 silicon	**15** 2.2 **P** 31.0 phosphorus	**16** 2.6 **S** 32.1 sulfur	**17** 3.2 **Cl** 35.5 chlorine	**18** **Ar** 39.9 argon
28 1.9 **Ni** 58.7 nickel	**29** 1.9 **Cu** 63.5 copper	**30** 1.7 **Zn** 65.4 zinc	**31** 1.8 **Ga** 69.7 gallium	**32** 2.0 **Ge** 72.6 germanium	**33** 2.2 **As** 74.9 arsenic	**34** 2.6 **Se** 79.0 selenium	**35** 3.0 **Br** 79.9 bromine	**36** 3.0 **Kr** 83.8 krypton
46 2.2 **Pd** 106.4 palladium	**47** 1.9 **Ag** 107.9 silver	**48** 1.7 **Cd** 112.4 cadmium	**49** 1.8 **In** 114.8 indium	**50** 2.0 **Sn** 118.7 tin	**51** 2.1 **Sb** 121.8 antimony	**52** 2.1 **Te** 127.6 tellurium	**53** 2.7 **I** 126.9 iodine	**54** 2.6 **Xe** 131.3 xenon
78 2.3 **Pt** 195.1 platinum	**79** 2.5 **Au** 197.0 gold	**80** 2.0 **Hg** 200.6 mercury	**81** 1.6 **Tl** 204.4 thallium	**82** 2.3 **Pb** 207.2 lead	**83** 2.0 **Bi** 209.0 bismuth	**84** 2.0 **Po** (210) polonium	**85** 2.2 **At** (210) astatine	**86** **Rn** (222) radon
110 **Ds** (271) darmstadtium	**111** **Rg** (272) roentgenium	**112** **Cn** (285) copernicium	**113** **Nh** (280) nihonium	**114** **Fl** (289) flerovium	**115** **Mc** (289) moscovium	**116** **Lv** (292) livermorium	**117** **Ts** (294) tennessine	**118** **Og** (294) oganesson

64 1.2 **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** 1.2 **Dy** 162.5 dysprosium	**67** 1.2 **Ho** 164.9 holmium	**68** 1.2 **Er** 167.3 erbium	**69** 1.3 **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** 1.3 **Lu** 175.0 lutetium

96 1.3 **Cm** (247) curium	**97** 1.3 **Bk** (247) berkelium	**98** 1.3 **Cf** (251) californium	**99** 1.3 **Es** (252) einsteinium	**100** 1.3 **Fm** (257) fermium	**101** 1.3 **Md** (258) mendelevium	**102** 1.3 **No** (259) nobelium	**103** 1.3 **Lr** (262) lawrencium

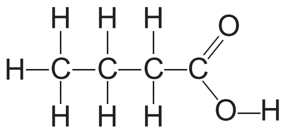
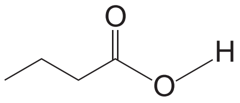
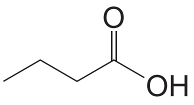
Values in brackets indicate the mass number of the longest-lived isotope.

17. Names of selected elements

Element	Symbol	Atomic number	Relative atomic mass (amu)	Element	Symbol	Atomic number	Relative atomic mass (amu)
aluminium	Al	13	27.0	magnesium	Mg	12	24.3
argon	Ar	18	39.9	manganese	Mn	25	54.9
arsenic	As	33	74.9	mercury	Hg	80	200.6
barium	Ba	56	137.3	neon	Ne	10	20.2
beryllium	Be	4	9.0	nickel	Ni	28	58.7
boron	B	5	10.8	nitrogen	N	7	14.0
bromine	Br	35	79.9	oxygen	O	8	16.0
cadmium	Cd	48	112.4	phosphorus	P	15	31.0
caesium	Cs	55	132.9	platinum	Pt	78	195.1
calcium	Ca	20	40.1	potassium	K	19	39.1
carbon	C	6	12.0	rubidium	Rb	37	85.5
chlorine	Cl	17	35.5	scandium	Sc	21	45.0
chromium	Cr	24	52.0	selenium	Se	34	79.0
cobalt	Co	27	58.9	silicon	Si	14	28.1
copper	Cu	29	63.5	silver	Ag	47	107.9
fluorine	F	9	19.0	sodium	Na	11	23.0
gallium	Ga	31	69.7	strontium	Sr	38	87.6
germanium	Ge	32	72.6	sulfur	S	16	32.1
gold	Au	79	197.0	tin	Sn	50	118.7
helium	He	2	4.0	titanium	Ti	22	47.9
hydrogen	H	1	1.0	tungsten	W	74	183.8
iodine	I	53	126.9	vanadium	V	23	50.9
iron	Fe	26	55.8	xenon	Xe	54	131.3
krypton	Kr	36	83.8	yttrium	Y	39	88.9
lead	Pb	82	207.2	zinc	Zn	30	65.4
lithium	Li	3	6.9	zirconium	Zr	40	91.2

18. Representations of organic molecules

The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	 or 

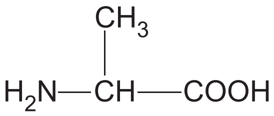
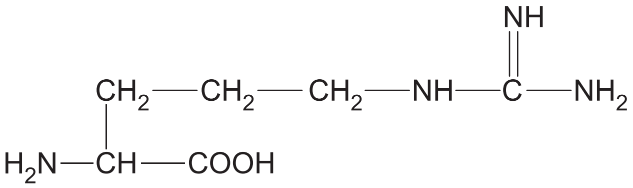
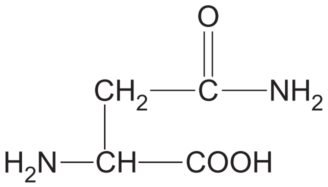
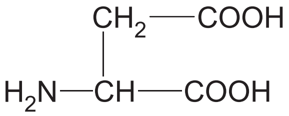
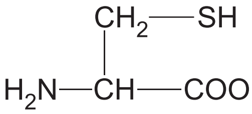
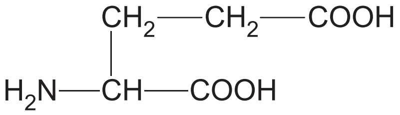
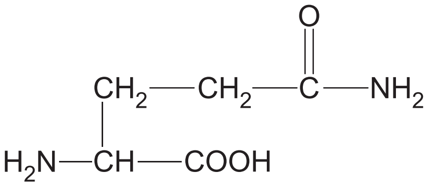
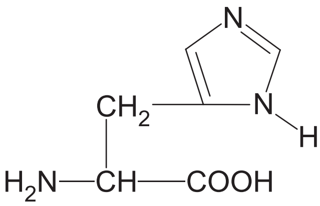
19. Functional group nomenclature in organic chemistry

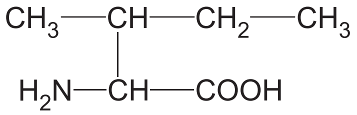
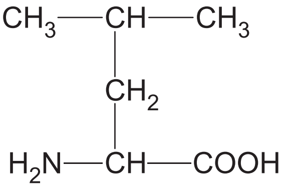
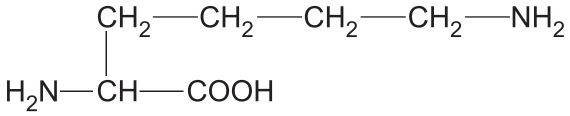
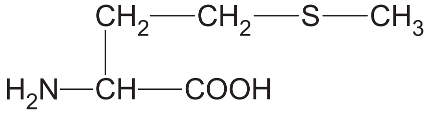
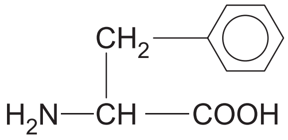
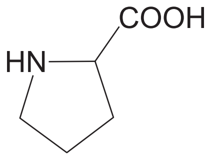
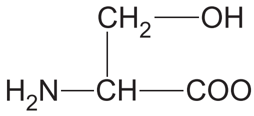
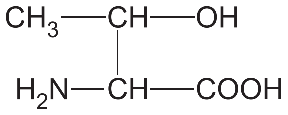
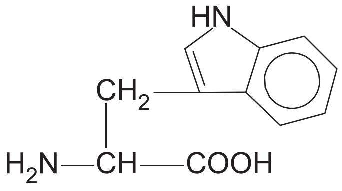
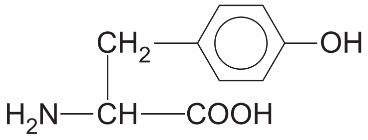
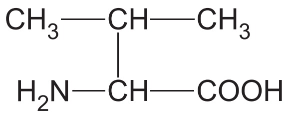
The following table shows the priority of functional groups when naming organic compounds that contain more than one functional group.
The functional group with the highest priority determines the suffix of the compound.

Class of compound	Functional group name	Prefix	Suffix
carboxylic acid	carboxyl	–	-oic acid
ester	ester	–	-oate
amide	amide	–	-amide
aldehyde	carbonyl	–	-al
ketone	carbonyl	–	-one
alcohol	hydroxy/ hydroxyl	hydroxy-	-ol
amine	amino	amino-	-amine
alkene	alkenyl	–	-ene
halogen	‘halo’ (i.e. bromo, chloro, fluoro, iodo)	bromo- chloro- fluoro- iodo-	–

20. 2-amino acids (α-amino acids)

The table below provides simplified structures for amino acids. These amino acids may all be classified as ‘2-amino acids’ since the amino group (-NH_2) is attached to the second carbon atom in the carbon chain, numbered from the carboxyl (-COOH) end. They may also be classified as ‘α-amino acids’, since both the amino group and the carboxyl group are attached to the same carbon atom, known as the alpha carbon. These structures may be used as the basis for drawing zwitterions, identifying the products of protein hydrolysis and drawing the structures formed in the condensation polymerisation of amino acid monomers.

Name	Symbol	Structure
alanine	Ala	 $H_2N-\overset{\overset{CH_3}{\vert}}{CH}-COOH$
arginine	Arg	 $H_2N-\overset{\overset{CH_2-CH_2-CH_2-NH-\overset{\overset{NH}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
asparagine	Asn	 $H_2N-\overset{\overset{CH_2-\overset{\overset{O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
aspartic acid	Asp	 $H_2N-\overset{\overset{CH_2-COOH}{\vert}}{CH}-COOH$
cysteine	Cys	 $H_2N-\overset{\overset{CH_2-SH}{\vert}}{CH}-COOH$
glutamic acid	Glu	 $H_2N-\overset{\overset{CH_2-CH_2-COOH}{\vert}}{CH}-COOH$
glutamine	Gln	 $H_2N-\overset{\overset{CH_2-CH_2-\overset{\overset{O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	

Name	Symbol	Structure
isoleucine	Ile	 $\begin{array}{l} CH_3-CH-CH_2-CH_3 \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
leucine	Leu	 $\begin{array}{l} CH_3-CH-CH_3 \\ \qquad\ \vert \\ \qquad CH_2 \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
lysine	Lys	 $\begin{array}{l} \qquad CH_2-CH_2-CH_2-CH_2-NH_2 \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
methionine	Met	 $\begin{array}{l} \qquad CH_2-CH_2-S-CH_3 \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
phenylalanine	Phe	
proline	Pro	
serine	Ser	 $\begin{array}{l} \qquad CH_2-OH \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
threonine	Thr	 $\begin{array}{l} CH_3-CH-OH \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	 $\begin{array}{l} CH_3-CH-CH_3 \\ \qquad\ \vert \\ H_2N-CH-COOH \end{array}$

21. Formulas of selected fatty acids

Name	Molecular formula	Semi-structural formula
caproic	$C_6H_{12}O_2$	$CH_3(CH_2)_4COOH$
capric	$C_{10}H_{20}O_2$	$CH_3(CH_2)_8COOH$
lauric	$C_{12}H_{24}O_2$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{14}H_{28}O_2$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{16}H_{30}O_2$	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$
stearic	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{18}H_{34}O_2$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic	$C_{18}H_{32}O_2$	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$
linolenic	$C_{18}H_{30}O_2$	$CH_3(CH_2CH{=}CH)_3(CH_2)_7COOH$
arachidic	$C_{20}H_{40}O_2$	$CH_3(CH_2)_{18}COOH$
arachidonic	$C_{20}H_{32}O_2$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

22. Characteristic ranges for infrared absorption

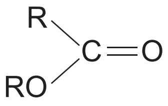
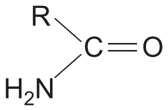
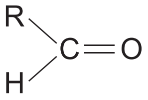
Bond	Wave number (cm^{-1})
C=O (amides)	1630–1680
C=O (aldehydes)	1660–1745
C=O (acids)	1680–1740
C=O (ketones)	1680–1850
C=O (esters)	1720–1840

Bond	Wave number (cm^{-1})
C–H (alkanes, alkenes, arenes)	2850–3090
O–H (acids)	2500–3500
O–H (alcohols)	3200–3600
N–H (amines and amides)	3300–3500

23. ^{13}C NMR data

Typical ^{13}C shift values relative to TMS = 0

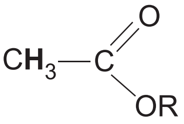
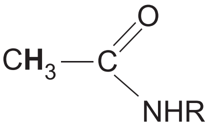
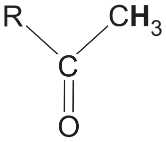
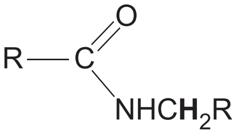
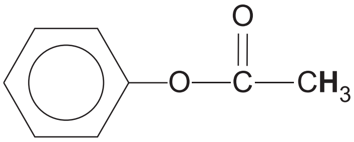
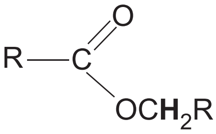
These can differ slightly in different solvents.

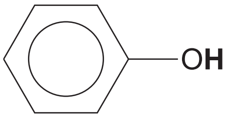
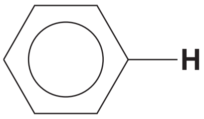
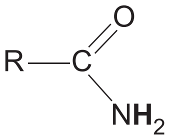
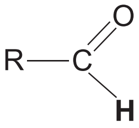
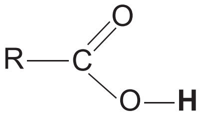
Type of carbon	Chemical shift (ppm)
$R{-}CH_3$	8–25
$R{-}CH_2{-}R$	20–45
$R_3{-}CH$	40–60
$R_4{-}C$	36–45
$R{-}CH_2{-}X$	15–80
$R_3C{-}NH_2$, $R_3C{-}NR$	35–70
$R{-}CH_2{-}OH$	50–90
$R_2C{=}CR_2$	110–150
arenes $C_6H_5{-}R$	110–150
RCOOH	160–185
 $R(RO)C{=}O$	165–175
 $R(H_2N)C{=}O$	165–185
 $R(H)C{=}O$	190–200
$R_2C{=}O$	205–220

24. ^{1}H NMR data

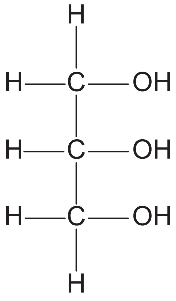
Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

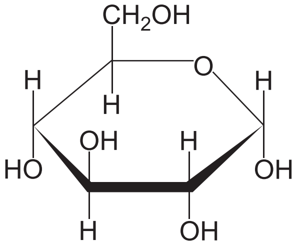
Type of proton	Chemical shift (ppm)
$\mathrm{R{-}C}\mathbf{H}_3$	0.9–1.0
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}R}$	1.3–1.4
$\mathrm{RCH{=}CH{-}C}\mathbf{H}_3$	1.6–1.9
$\mathrm{R_3{-}C}\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}X}$ (X = F, Cl, Br or I)	3.0–4.5
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}OH}$, $\mathrm{R_2{-}C}\mathbf{H}\mathrm{{-}OH}$	3.3–4.5
	3.2
$\mathrm{R{-}O{-}C}\mathbf{H}_3$ or $\mathrm{R{-}O{-}C}\mathbf{H}_2\mathrm{R}$	3.3–3.7
	2.3
	3.7–4.8
$\mathrm{R{-}O{-}}\mathbf{H}$	1–6 (varies considerably under different conditions)
$\mathrm{R{-}N}\mathbf{H}_2$	1–5
$\mathrm{RHC{=}C}\mathbf{H}\mathrm{R}$	4.5–7.0

Type of proton	Chemical shift (ppm)
	4.0–12.0
	6.9–9.0
	6.0–8.0
	9.4–10.0
	9.0–13.0

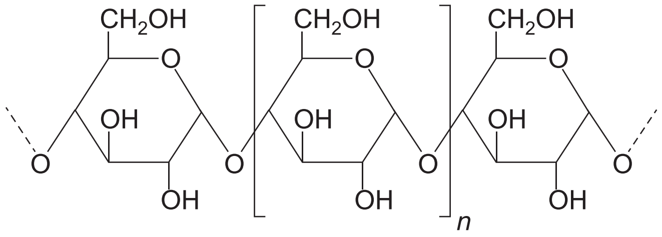
25. Representations of selected biomolecules



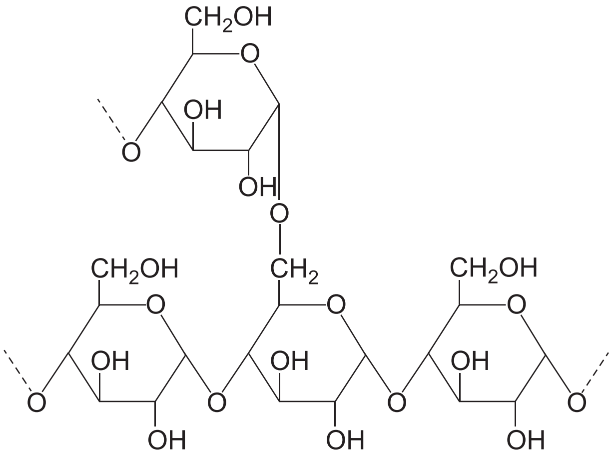
glycerol



α-D-glucose



amylose (starch)



amylopectin (starch)

26. Sustainability

i. United Nations Sustainable Development Goals

The following nine goals are relevant to VCE Chemistry:

- Goal 2: Zero hunger
- Goal 6: Clean water and sanitation
- Goal 7: Affordable and clean energy
- Goal 9: Industry, innovation and infrastructure
- Goal 11: Sustainable cities and communities
- Goal 12: Responsible consumption and production
- Goal 13: Climate action
- Goal 14: Life below water
- Goal 15: Life on land

Source: Adapted from ‘The 17 Goals’,
Department of Economic and Social Affairs,
Sustainable Development, United Nations
<https://sdgs.un.org./goals>

ii. Green chemistry principles

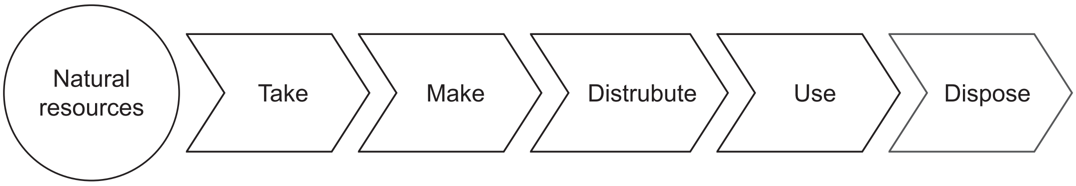
The following seven green chemistry principles are relevant to VCE Chemistry:

- Atom economy: Processes/pathways should be designed to maximise incorporation of all reactant materials used in the process into the final product.
- Catalysis: Catalysts should be selected to generate the same desired product(s) with less waste and using less energy and reagents in reaction processes/pathways.
- Design for degradation: Chemical products should be designed so that at the end of their use they break down into harmless degradation products and do not persist in the environment.
- Design for energy efficiency: Processes/pathways should be designed for maximum energy efficiency and with minimal negative environmental and economic impacts.
- Designing safer chemicals: Chemical products should be designed to achieve their intended function while minimising toxicity.
- Prevention of wastes: It is better to prevent waste than to treat or clean up waste after it has been produced.
- Use of renewable feedstocks: Raw materials or feedstocks should be made from renewable (mainly plant-based) materials, rather than from fossil fuels, whenever practicable.

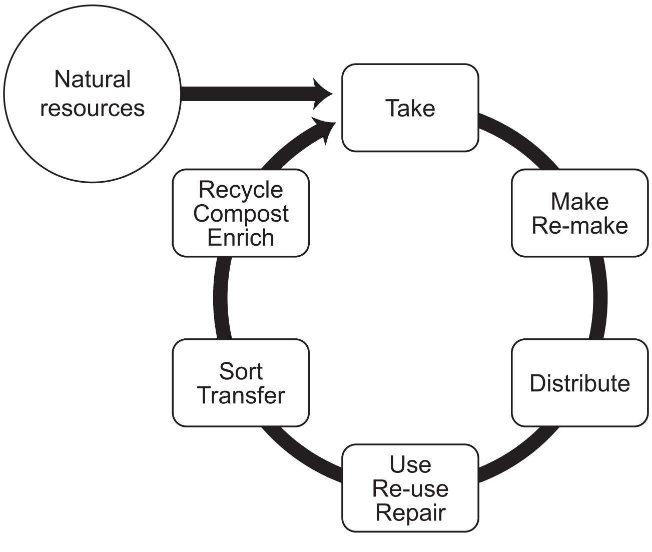
Source: Adapted from PT Anastas and JC Warner,
Green Chemistry: Theory and Practice, Oxford University Press, New York, 1998, p.30

iii. Types of economies

Linear



Circular



End of Chemistry Data Book